ELEMENTS OF HIGH VOLTAGE ELECTRON COOLING SYSTEM FOR NICA COLLIDER

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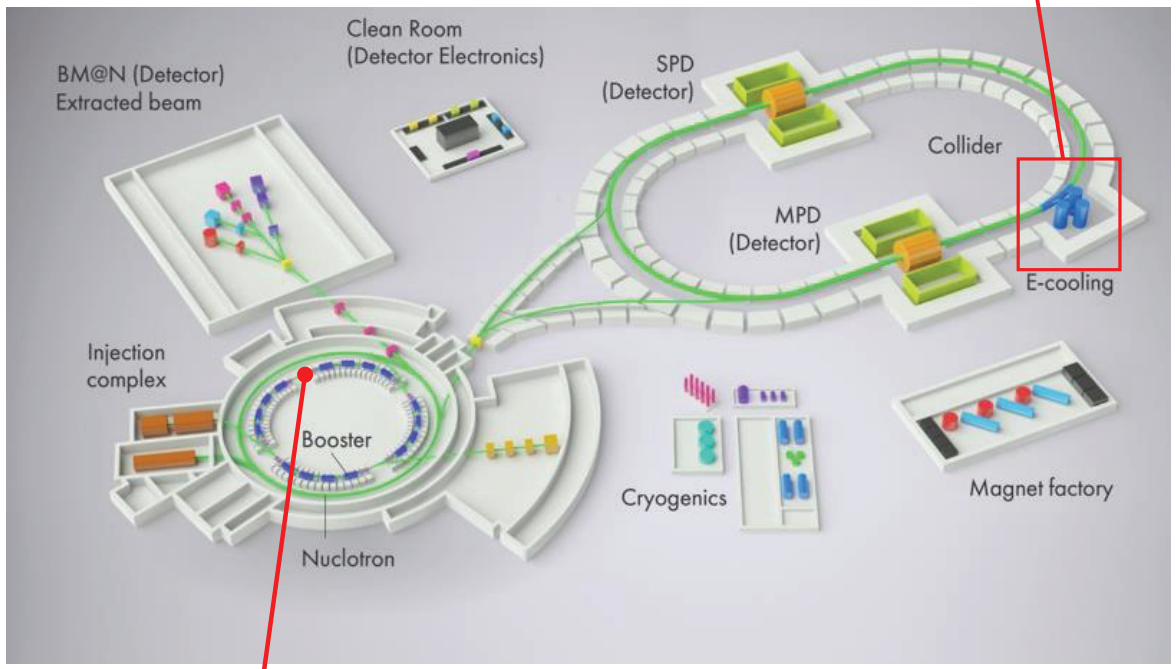
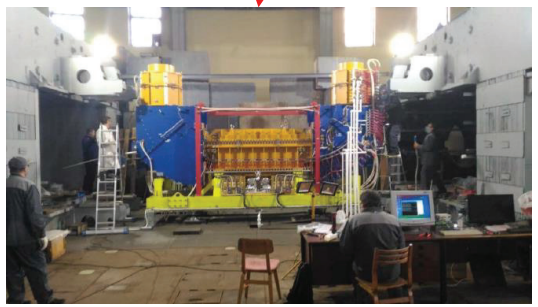
on behalf of BINP Electron Cooling team

High voltage electron cooling in the NICA collider

HV electron cooler





Electron cooling system for NICA booster (In September of 2021 first cooling was achieved!)

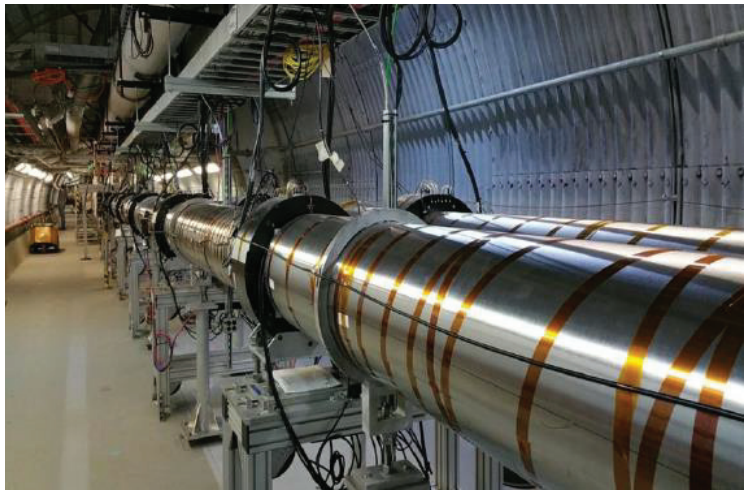
Parameters of the NICA collider

Parameter	Value		
Number of bunches	22		
RMS length of a bunch, m	0.6 m		
β-function at the IP, m	0.6 m		
Energy Au^{79+}, GeV / n	1.0	3.3	4.5
Number of ions in the bunch	$2 \cdot 10^{8}$	$2.4 \cdot 10^{9}$	$2.3 \cdot 10^{9}$
RMS momentum spread, $\Delta p/p$	$0.6 \cdot 10^{-3}$	$1.2 \cdot 10^{-3}$	$1.6 \cdot 10^{-3}$
RMS emittance, π·mm·mrad	1.10/1.1	1.10/0.9	1.10/0.8
Time of growth due IBS, s	160	530	1700
Luminosity, $cm^{-2} \cdot c^{-1}$	$0.6 \cdot 10^{25}$	$1.0 \cdot 10^{27}$	$1.0 \cdot 10^{27}$

Two cooling systems (electron and stochastic) will work both during beam accumulation and during experiment.

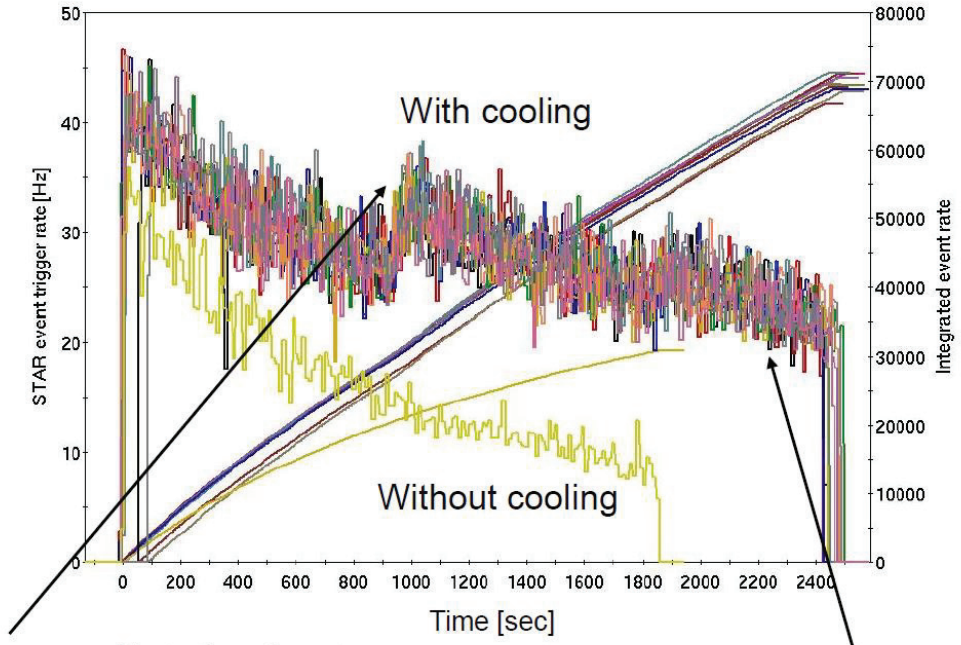
First electron cooling experience in collider

From: A. Fedotov et al., Operational Electron Cooling in RHIC, IPAC'21, Brazil, May 24-28, 2021



Electron cooler LEReC operated for RHIC physics program using 1.6 MeV kinetic energy electron beam to cool Au ions at 3.85 GeV/nucleon total energy and using 2 MeV electron beam to cool ions at 4.6 GeV/nucleon.

2020: Several physics stores at 4.6 GeV/nucleon with cooling: vertical axis: events rate [Hz] within +/-0.7m (left); store integrals (right)

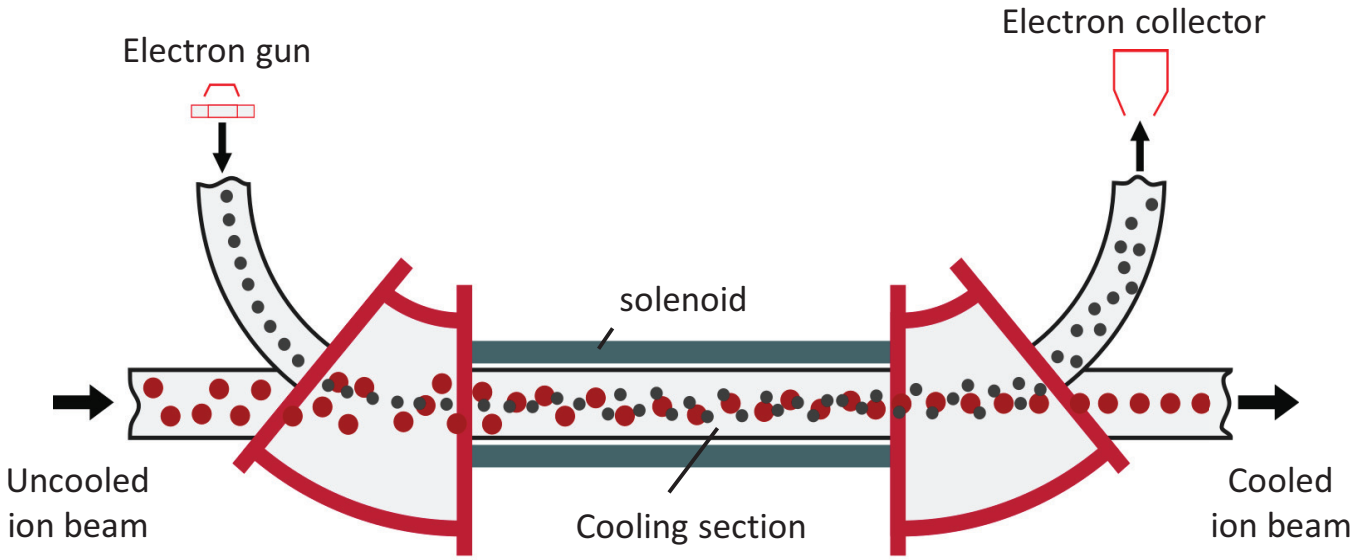


Dynamic squeeze of beta-function at collision point, while transverse beam sizes of ion beams are being cooled

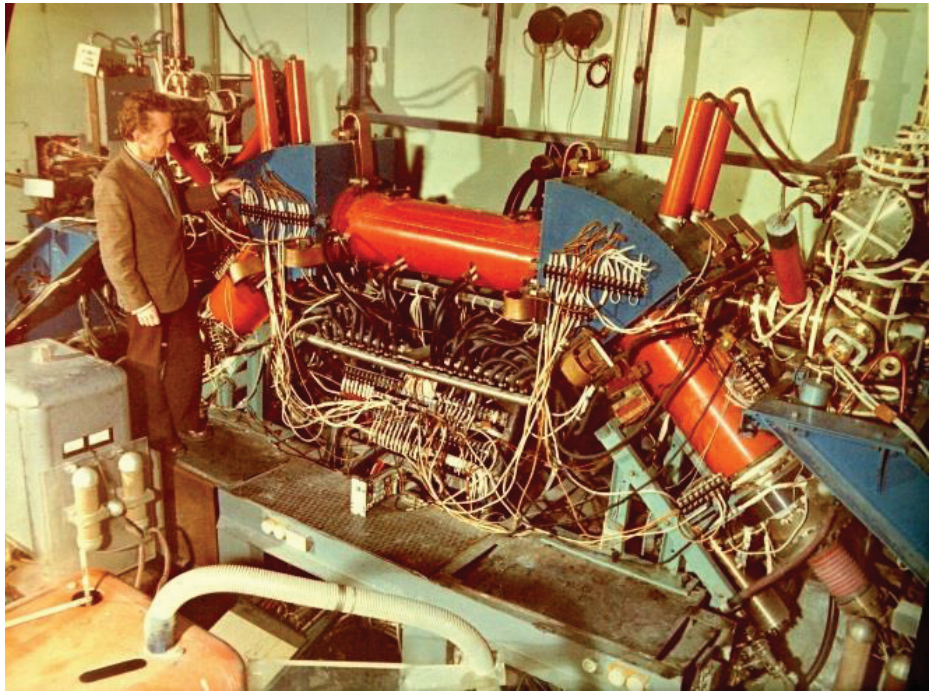
Longer stores with cooling

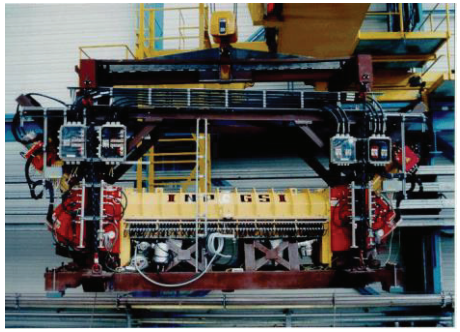
Gains in integrated luminosity from cooling:
2020 (4.6 GeV/n): about factor of 2
2021 (3.85 GeV/n): 30-50%

Electron cooling

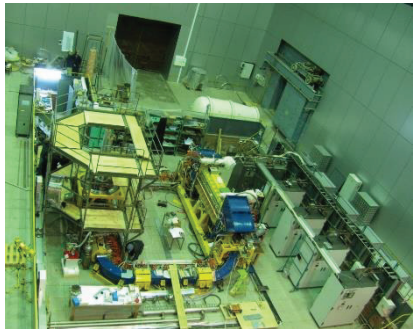


- circulating ion beam
- “cool” electron beam





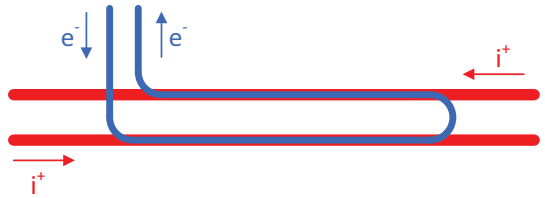





High voltage electron cooling in the NICA collider

The construction is based on HV ECS for COSY (Germany)

The HV ECS for NICA consists of two almost independent coolers. Scheme with one electron beam looks very complicated



Electron energy	0.2 - 2.5 MeV
Energy stability (ΔU/U)	$<10^{-4}$
Electron current	0.1 - 1 A
Cooling section length	6 m
Magnetic field in cooling section	0.5 - 2 kG
Vacuum	10^{-11} mbar

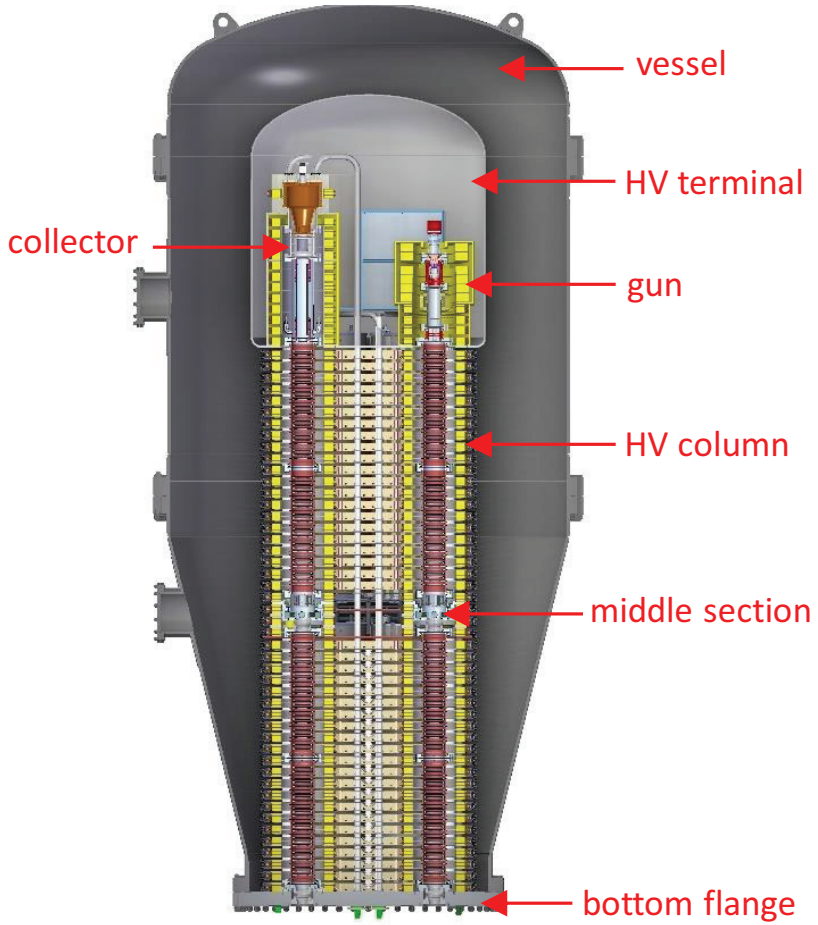
Main problems:

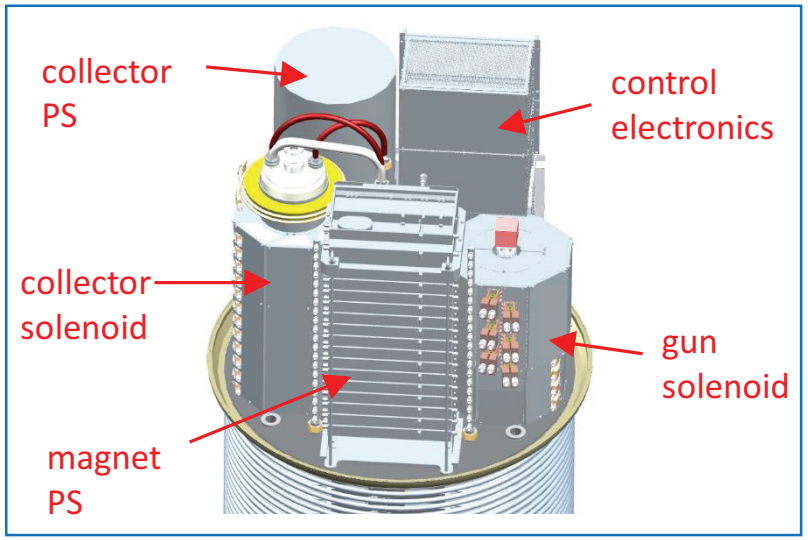
- High energy (up to 2.5 MeV);
- Small distance between beams (320 mm);
- Limited power consumption of the system (not more then 700 kW).

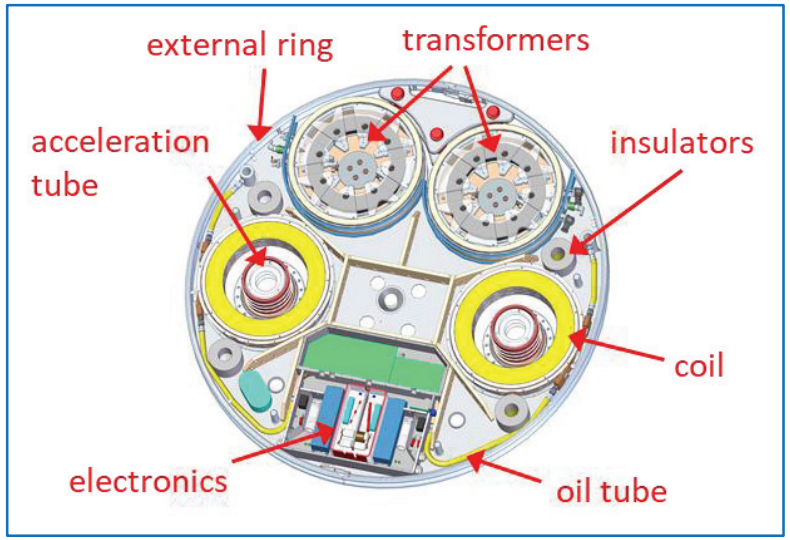
Comparison of the COSY and NICA HV coolers

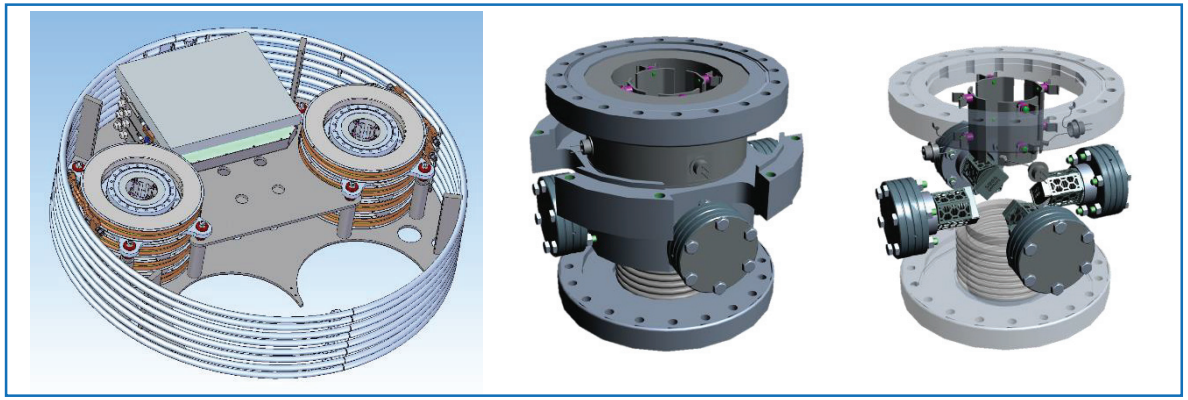
High voltage system

Purpose of the high voltage system is production of electron beam in electron gun and acceleration for working energy in electrostatic tube. After interaction with ion beam electrons flies to high voltage again where they are decelerated in another electrostatic tube and dumped in electron collector.





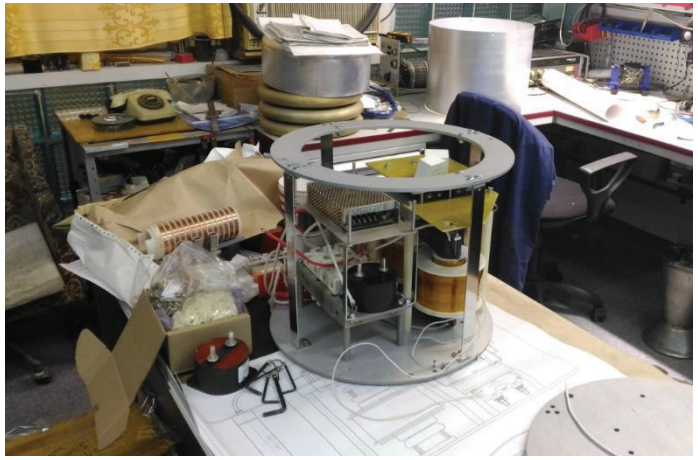




High voltage system production

Electron gun

High voltage section



Collector PS

Wien filters

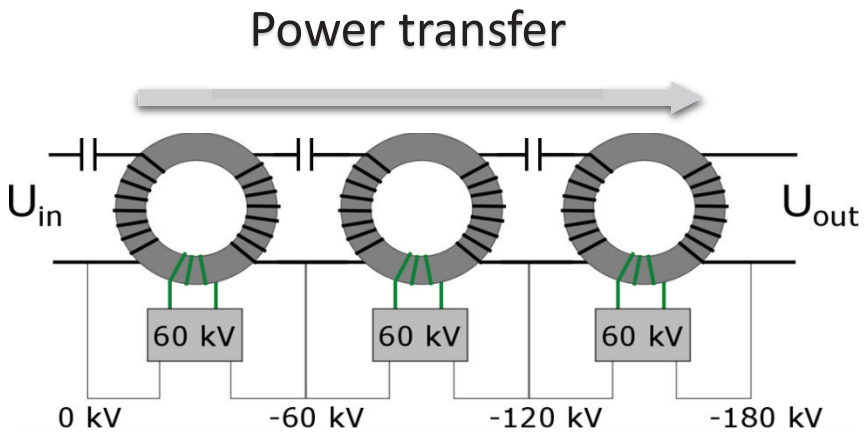
High voltage column

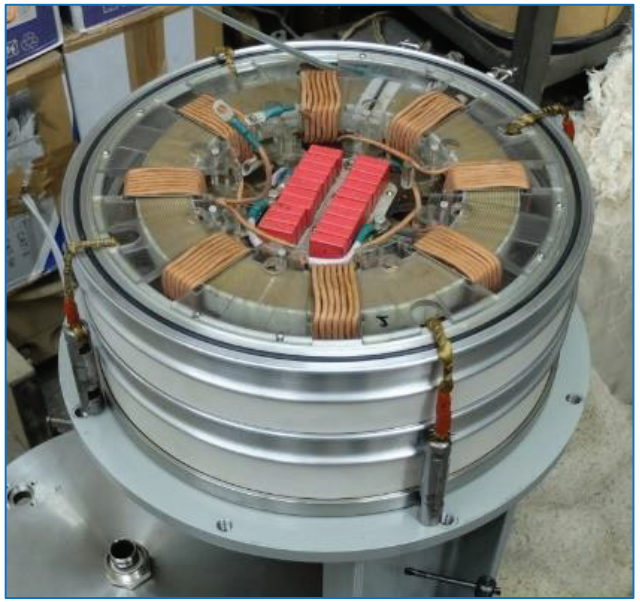
Middle section

High voltage terminal

Gun-collector control electronics

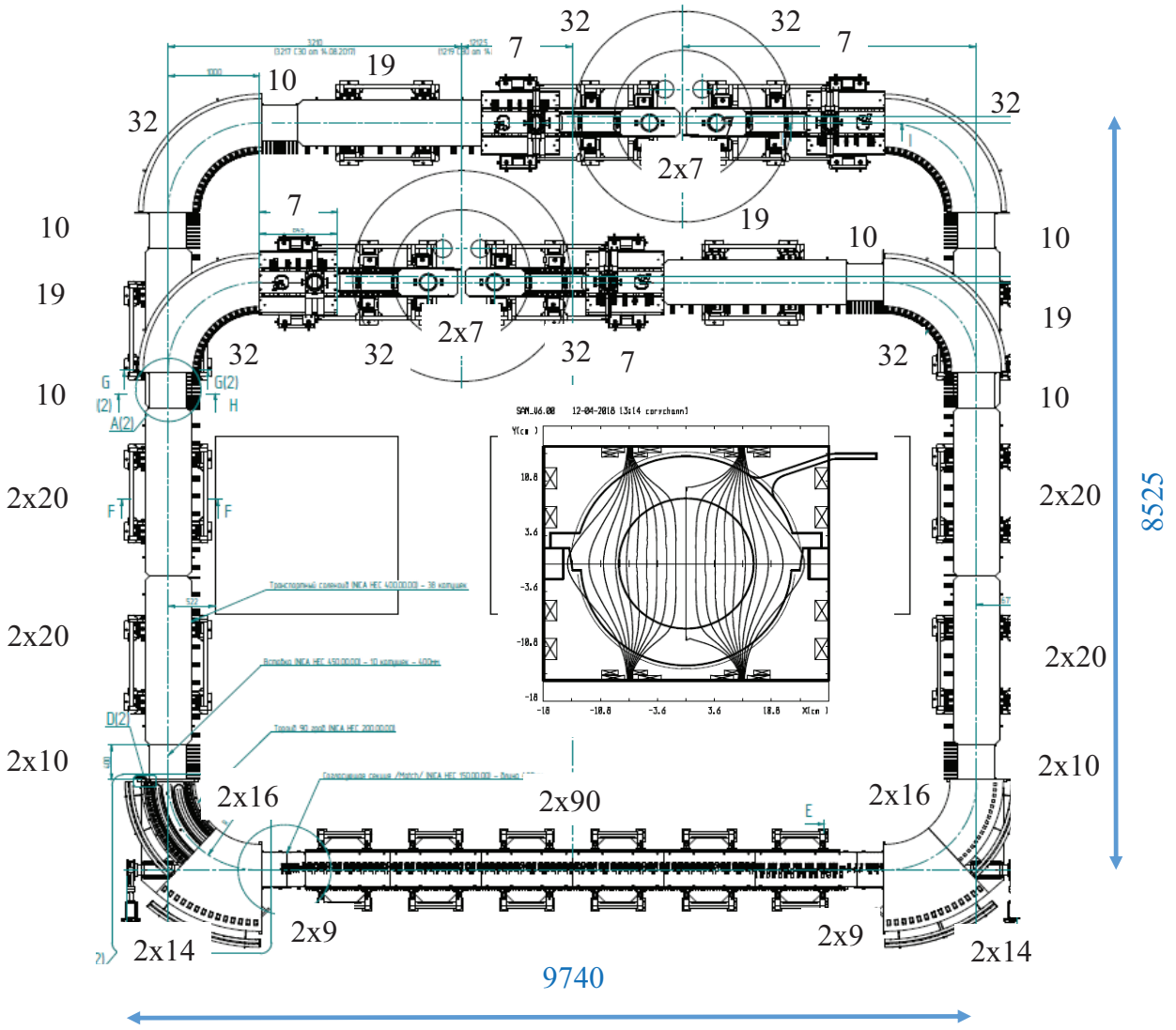
Cascade transformer





Magnetic system

Electrons move on whole trajectory from gun to collector in longitudinal magnetic field. Transport channels consist of set of straight and bend solenoids.

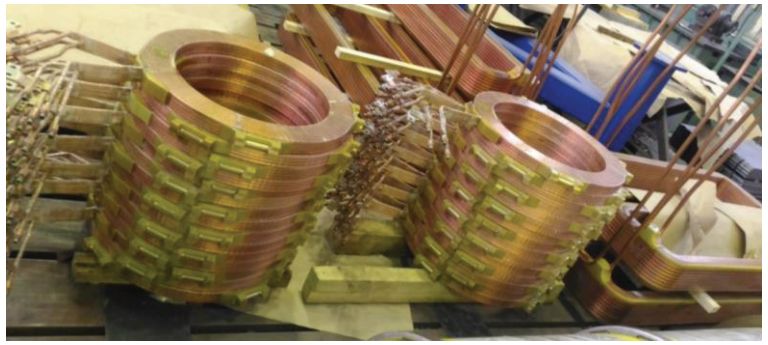


<u>Longitudinal magnetic field</u>

Cooling section –	180
Small toroids coils –	66
Large toroids coils –	60
Match sections –	48
Insert section –	110
Line transport section –	250
Bend section –	260
Line08 –	30
Hmatch section –	28
High Voltage Section –	180
HV Terminal –	46

In total 20 types of coil for longitudinal magnetic field

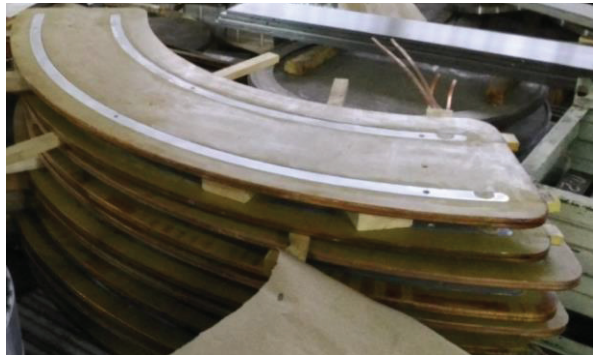
Magnetic system

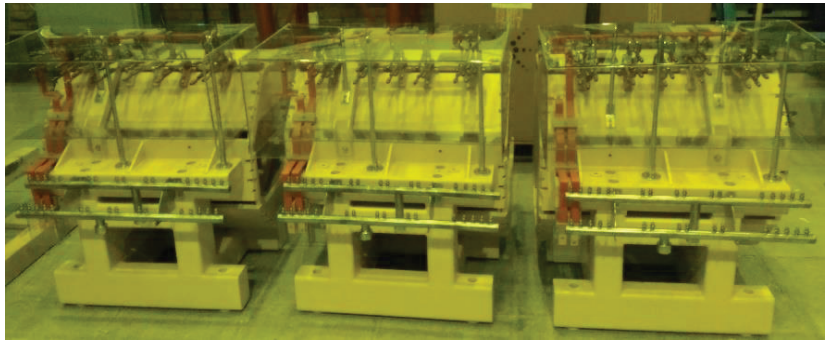


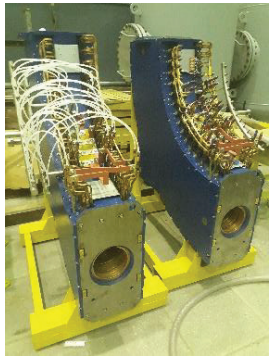






Magnetic system





Electronics

BPM electronics

BPM preamplifiers

Interlock system

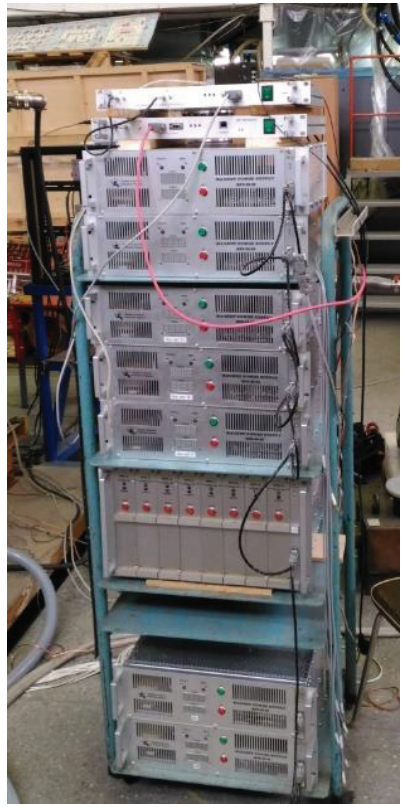
Test of BPM electronics on “Gun-Collector” test bench

Can-Ethernet gateway

Power supplies

High current (IST) PS

Cascade transformer PS

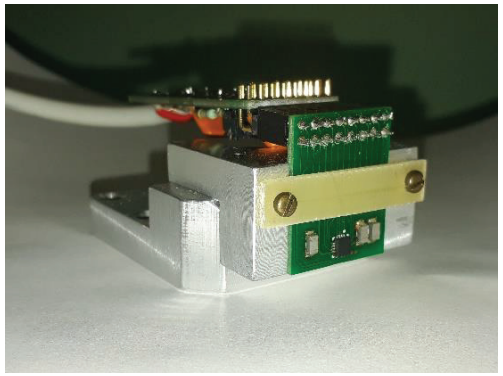


Low current (corrector) PS

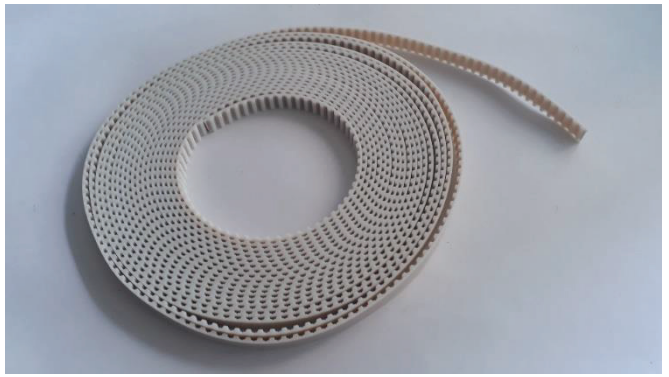
Hall for ECS commissioning in the BINP

Magnetic measurements (Hall)

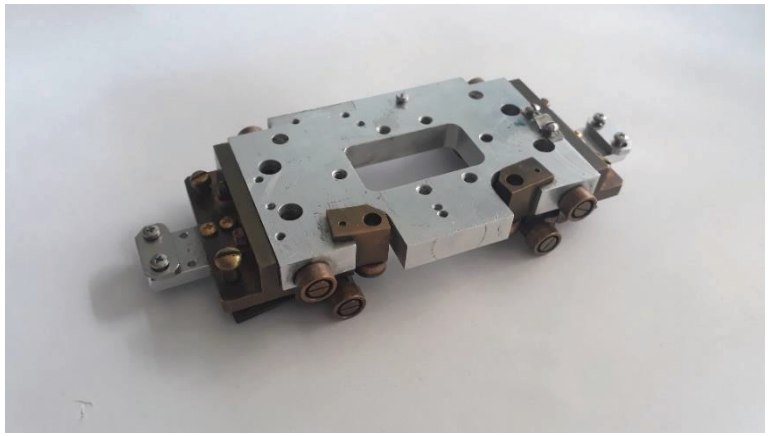
Hall probe measurement system contains set of straight and bent rails, which can be assembled n different way in order to measure magnetic filed distribution in different parts of the cooler.



3-D Hall probe



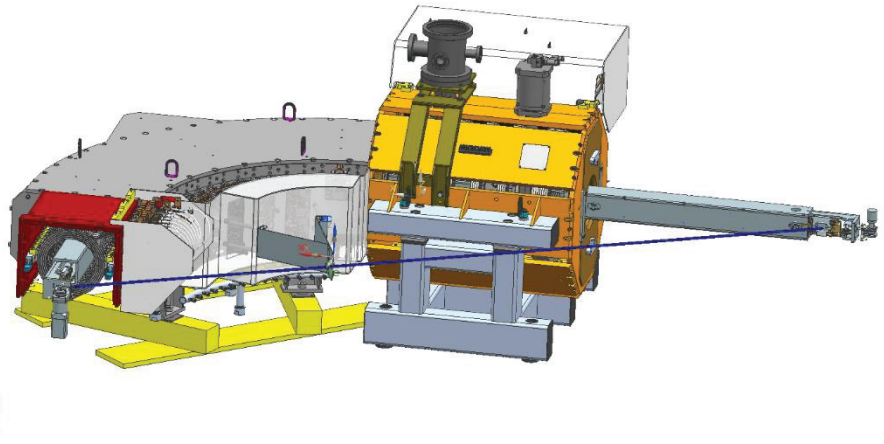
Tape

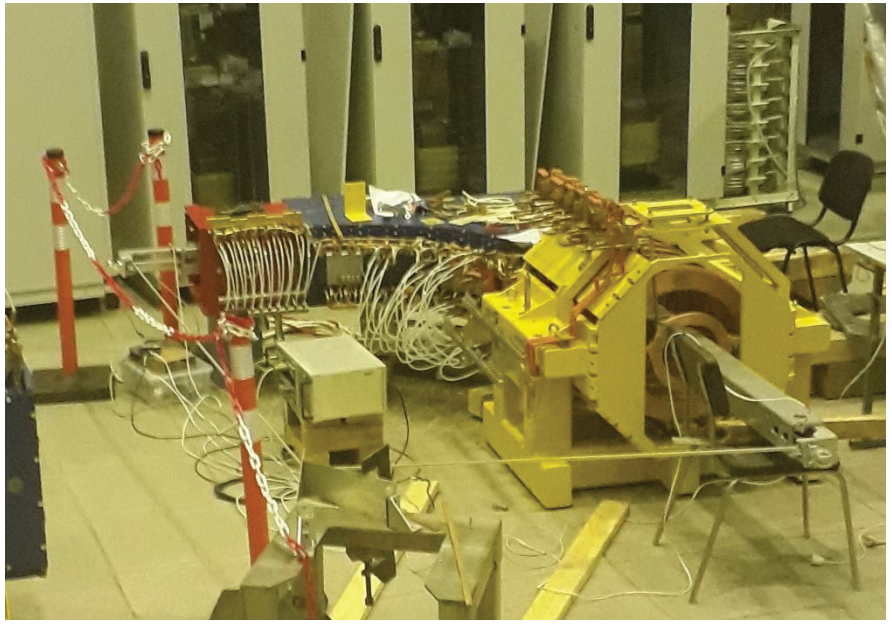


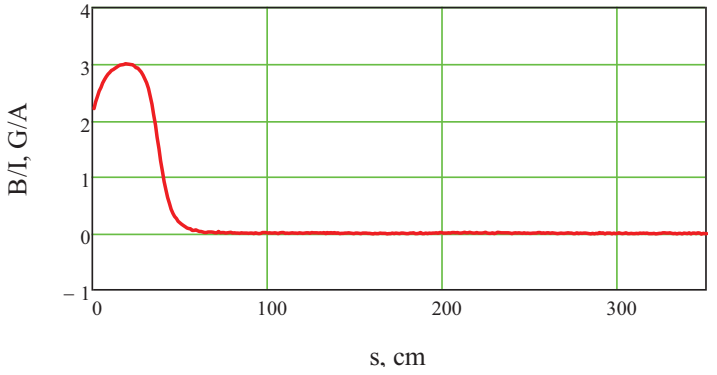
Carriage for Hall probe

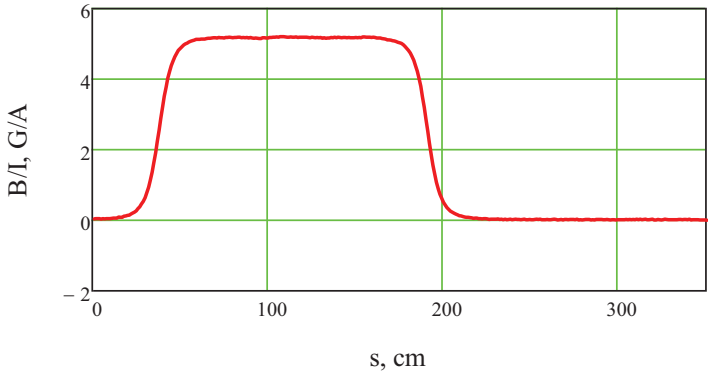
Square-shaped rail

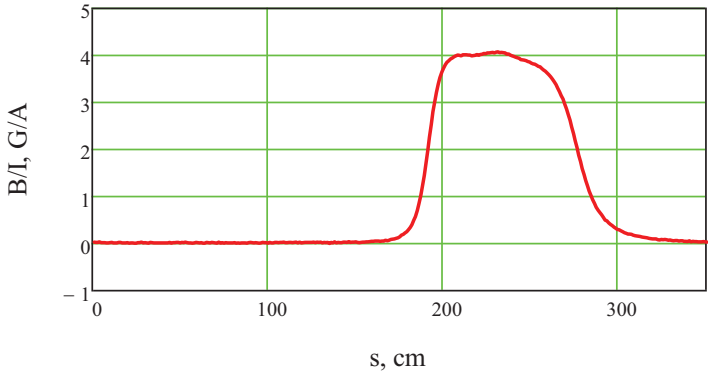
Magnetic measurements (Hall)





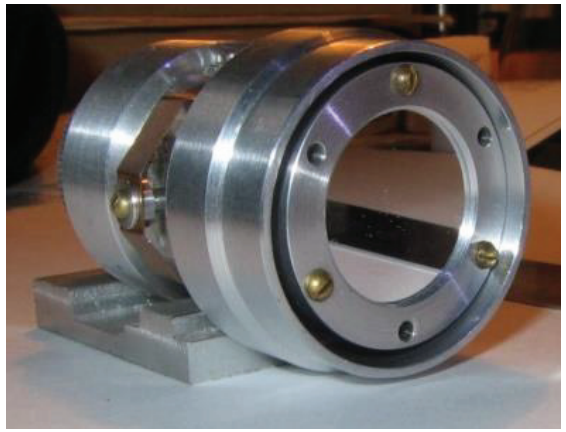






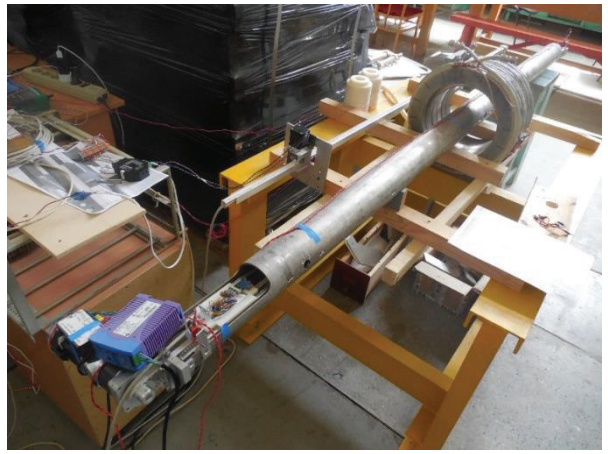
Magnetic measurements (compass)

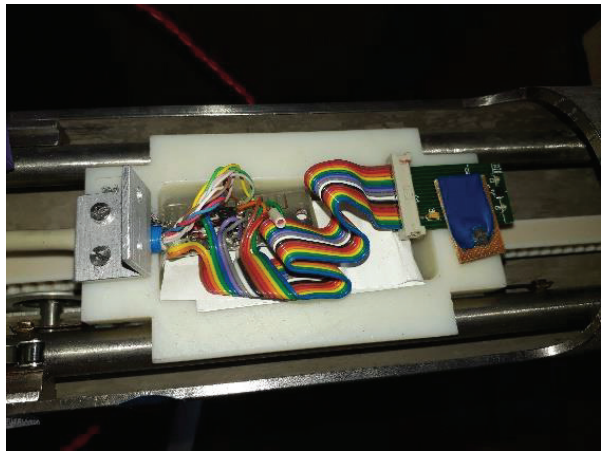
Compass sensor provides high precision measurements of magnetic line straightness.

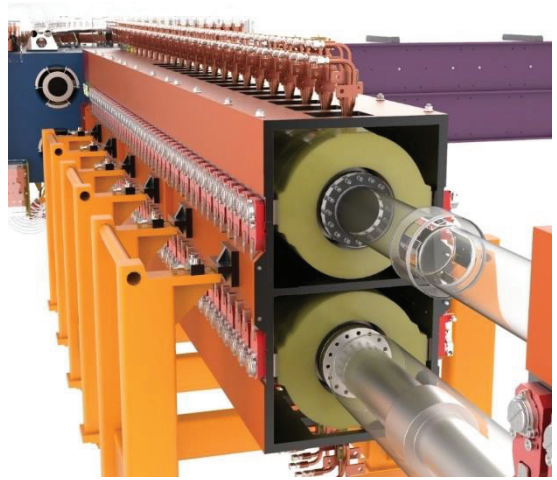


Scheme of compass measurements

Magnetic measurements (compass)

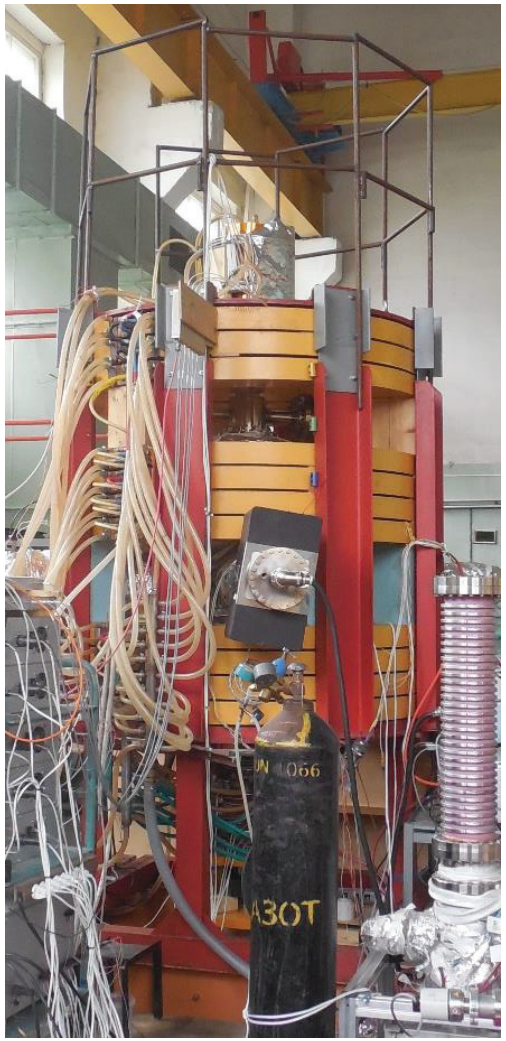


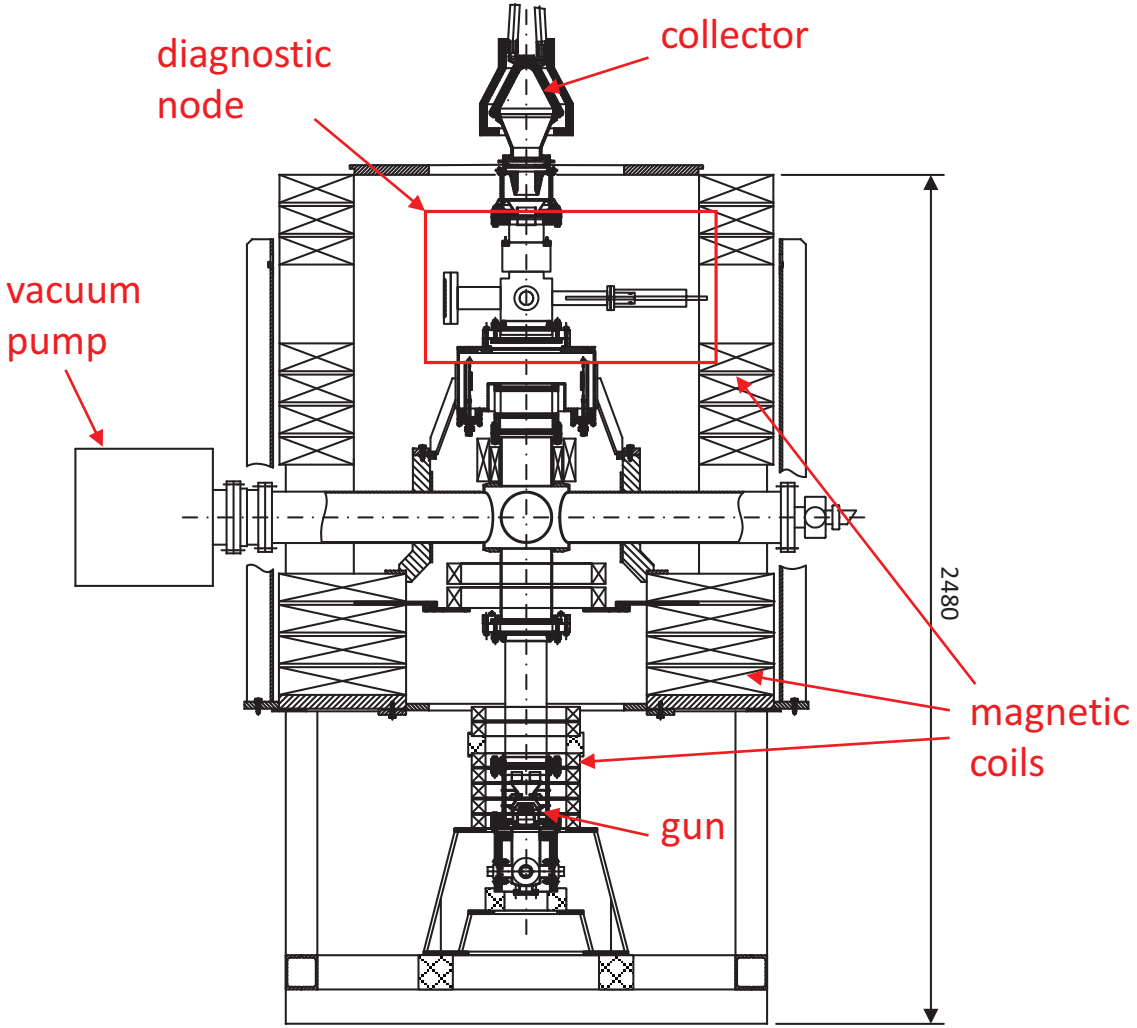




“Gun-collector” test bench

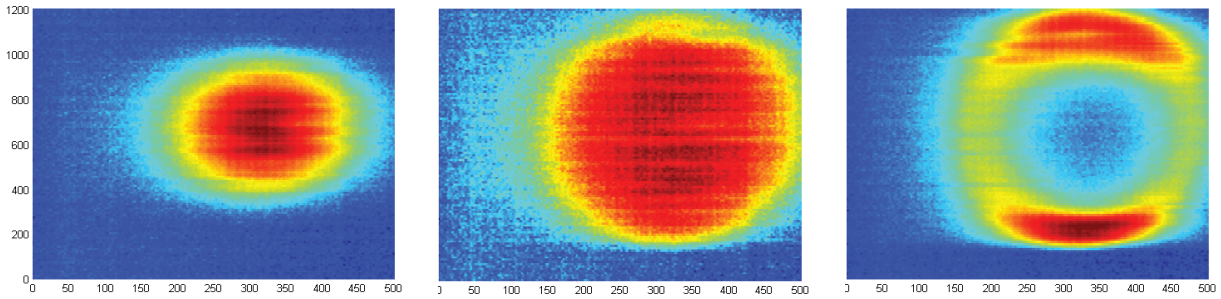
The test bench is assembled to test new electron gun. Its diagnostic node contains BPM and wire profile monitor and provides measurements both profile and temperature of the electron beam.



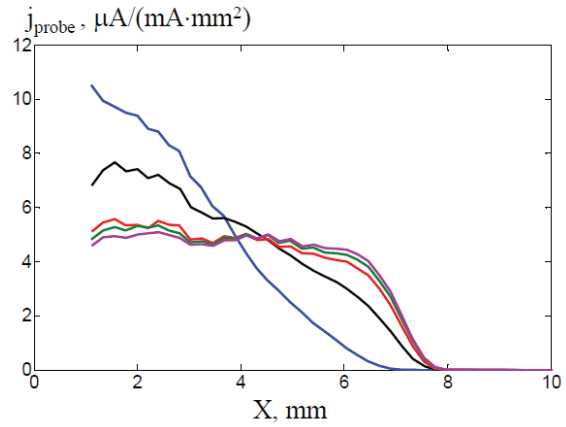


Diagnostic node

With the help of the wire profile monitor one can measure both current from the wire with ADC and wire glow (induced by beam) with CCD camera



Camera measurement



Current measurement

Thankyou for your attention!